Technical efficiency under resource scarcity: Non-parametric approach Uzbekistan agriculture

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Paper prepared for presentation at the EAAE 2011 Congress
Change and Uncertainty
Challenges for Agriculture,
Food and Natural Resources

August 30 to September 2, 2011
ETH Zurich, Zurich, Switzerland

Abstract

Water scarcity and land degradation increases led to a sharp rise in input resource's costs. These developments make it increasingly difficult for agricultural farms to produce according to the demand for food and other commodities, especially owing a rapid population growth. The present study aims to focus on scarce resource use in the agricultural production of the Zarafshan valley by means of the efficiency analysis. A DEA model is estimated to investigate the farm level efficiency levels with respect to the use of the limited resources available to the farmers. By the application of linear programming methods a 'best practice frontier is estimated', classifying farms on the frontier as efficient and others as inefficient with respect to different scales. Technical and allocative efficiencies are calculated relative to the frontier. Results shows input resources are not used efficiently and a great majority of farms could effectively reduce considerable amounts of input use by still producing the same output.

Introduction

A share of agriculture of Uzbekistan is decreasing, but still plays an important role in the economy. Agricultural contribution accounts 18 percent of GDP, and about 17.0 million or 60 percent of population of the country lives in rural areas, whereas 34 percent of them are involved into the agricultural production. Therefore, the main objectives of Uzbekistan's agricultural policy nowadays are: to achieve food security/self-sufficiency in grain production; to improve rural standards of living; maximize and stabilize export revenues from agricultural outputs and so on (MAWR, 2010, Guadagni, 2005, Mukhitdinova, 2010, Djalalov, 2006).

The country's agriculture is having structural changes gradually. Since its independence in 1991, an early stage of agricultural development was the transformation of the state and collective farms into cooperative and private farms. Nowadays, agricultural commodities are being produced mostly by private farms (*farmer*) and households (*dehqon*), also a small amount is being produced by cooperatives (*shirkats*) where production share and land occupation in agriculture consists of a small amount. The main agricultural products- cotton and grain, which have a state procurement price, are also being produced by private farms. Households are playing a significant role in producing food crops, which are 84 % of potato, 67 % vegetables, 52 % of fruits and nearly the whole share of meat and milk in the country is being produced by them(SCS Uz., 2009).

Agricultural production in the country concerns how efficiently the input resources are being used, especially, such as land and water. Due to unsustainable agricultural systems, water scarcity and land degradation, the cost of these resources in the past years have rapidly increased and are expected to additionally rise in the near future. Irrigation plays a key factor of agriculture and almost all crops produced in the country are taken from irrigated lands. The main sources of water for irrigation come from neighbor countries and its scarcity pressurizes most of the farms. These evidences make it increasingly difficult for farmers to produce according to the demand for food and other commodities, especially owing to a fast population growth.

The paper focuses on efficiency use of resources in the agricultural farms of Samarkand region, Uzbekistan. The primary data used in this research, cover nearly all aspects of agricultural production of farms. In the previous step of the research a Data Envelopment Analysis (DEA) approach is used to investigate trends in the farm sector, including the maximisation of economic value of agricultural production within the framework of scarce input resources use. This is a system approach widely used in management sciences and economics, in which the relationships between all inputs and outputs are taken into account simultaneously (Speelman et.al., 2008, Raju and Kumar, 2006).

Methodology

Efficiency refers relationship between outputs and inputs while it will achieve farmer's output in a more profitable manner. Estimation of efficiency began with the work of Farrell (1957) who explains the concept of a firms' efficiency considering multiple inputs (Coelli, 1995). Several studies have done increasing efficiency of irrigated agriculture system in whole, and also with special inputs or crops during the pre and independence period of the country (Abduganiev, 1983; Murtazaev, 2005). These studies were restricted to measure of efficiency in a simple economic and statistical way, instead of using research models more common, nowadays with special softwares.

Farm performance can be evaluated by technical, allocative and economic efficiency. A technical efficiency meaning is the ability of farm to produce the maximum feasible output from a given bundle of inputs or to use minimum feasible amounts of inputs to produce a given level of output. These two definitions are known as 'output-oriented' and 'input-oriented' measures of efficiency. Allocative efficiency measures the use of inputs in optimal quantities at the given prices. A combination of technical and allocative efficiency will present a measure of economic or cost efficiency (Coelli et al., 2002; Speelman et al., 2008).

There are parametric and nonparametric approaches existing to estimate relative efficiency of farms. The parametric approach estimates production or cost functions using statistical techniques. In this study we used non-parametric approach, which has several advantages to efficiency measurement: it is not concerning to build functional form for the frontier technology and permits the construction of a surface over the data. The non-parametric DEA model builds a linear piece-wise function from empirical observation of inputs and outputs. By the application of linear programming methods 'best practice frontier is estimated', classifying farms on the frontier as efficient and others as inefficient with respect to different scales. 'Input oriented' models were chosen, where the main aim is to use resources more efficiently and not to increase production (Rodri´guez Di´az et al., 2004)

In this paper we use the first for CRS (constant returns to scale) conditions input oriented model proposed by Charnes, Cooper and Rhodes (1978) to calculate technical efficiencies relative to the frontier.

In the introduced DEA model here, N firms or Decision Making Units (DMUs), each producing M outputs by using K different inputs. For the *i*th farm data represented x_i -input column and y_i- output column vectors.

Based on the study data and by using the duality in linear programming, it is intended to solve the following envelopment problem (Coelli et al., 2005) (Eq.1):

$$\min_{\theta,\lambda} \theta$$

$$\text{St} \quad -y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$\lambda \geq 0$$

where θ is a scalar and λ is N*1 vector of constant. The value θ taken at the results is efficiency score of each farm. It will satisfy the condition θ≤1, with a value of 1 indicating a point on the frontier and hence a technically efficient farm. The first constraint ensures that output produced by the *i*th farm is smaller than that on the frontier. The second constraint limits the proportional decrease in input use, when θ minimized, to the input use achieved with the best observed technology. For VRS condition we should add following convexity constraint for the model:

$$N1'\lambda = 1$$

A number of software exists for solving the efficiency problem, like DEA Solver (SAITECH, 2003), EMS (Scheel, 2000), DEAP 2.1(Coelli, 1996) and so on. In this study we used DEAP 2.1, which is a freeware program and calculates projected values of inputs.

In the second step we tried provide productivity analysis. An appropriate framework to analyze the food crop output in Uzbekistan is the neo-classical growth model first proposed by Solow (1956). Basically, the productivity i.e. output or weighted food crop yield per ha, is assumed to be a function of fertilizer and seed used per ha, tractor and machinery usage, irrigation (payment for irrigation water per ha), labor cost per ha, and so on. The general formulation of the production function is Q=A(t) f(K,L) where Q denotes the output, K and L are, respectively, capital and labour. The factor A(t) measures productivity shifts over time which may be induced by technological progress as per land productivity is concerned. Uzbekistan farmers in following the assumption shall be tested: the country agriculture performance is dependant, productivity link to socio-economic issues. For this purpose a detail questionnaire was administered to farmers, comprising questions on family status, age, gender, health situation, nutritional status etc.

The following model is a reduced form model, as several issues linked to multicollineraity were detected(Eq.2):

$$Crop\,income = \alpha + \beta_1 landsize + \beta_2 Doctoralvis + \beta_3 seedcst + \beta_4 Tractcst + \beta_5 fertilizecst + \beta_6 labcst + u$$

The results do not approve the assumption that socio-economic factors play a dominant role in Uzbekistan agriculture. As expected, mainly machinery, and variable inputs such as seed and fertilizer are found to be detrimental to achieved farm incomes. Table 3 presents the results of the OLS Regression.

Study Site and data collection

The study area is Zarafshan valley agriculture, Uzbekistan. Zarafshan valley is one of the biggest intermountain areas of Central Asia and is situated between the mountain ridges of Turkistan and Zarafshan. Historically, irrigated agriculture has well developed nearby the Zarafshan River, and nowadays, Uzbekistan's part of the valley occupies mainly 3 regions, as Samarkand, Navoiy and Bukhara and partly the southern areas of Jizzakh and the northern areas of Kashkadarya. The valley occupies around 1/5 of the country's irrigated land and produces 1/3 of the total agricultural commodities of Uzbekistan.

Since its independence 1991, three times a farm restructuring has been done in the agriculture of the country. In 1998 transforming from kolkhozes and sovkhozes into cooperatives and farms, then 2003 inefficient cooperatives restructured into farms, where agricultural share and land occupation of cooperatives (*shirkats)* has remained only 2%. The number of private farms in the country in 2008 was in peak 218.6 thousand with an average area of 27 ha in the country, as well as in the study area - Samarkand region 25.6 thousand private farms occupying 500.1 thousand hectares of land, where average size of farms was around 19.5 hectares. In this farms' sown area of cotton and wheat counted 30.1 % and 9.2 % respectively. The third period restructures began after the Presidential decree № 3077 in October 6, 2008, increasing or 'optimization' of land plots of farms, which is intended to merge of unprofitable, inefficiency farms and create a good opportunity for investment. The number of farms in the country and the study region is decreased to 81.3 and 9.1 thousands, but average size is increased up to 60.7 ha and 57.6 ha, respectively. As well as the main crops- wheat and cotton oriented farm plot areas consists 92 ha and 110 ha (MAWR, 2010).

In early 2010 a survey was carried out among private (farmer) and household (dehqon) farms mainly of the Samarkand and partly of the Navoiy and Kashkadarya region's counties. The survey questionnaires covered 102 farms and households, which random selection was insured. The main questions included the types and modes of input resources use, off- farm income sources, questions related to farm management and other socio-economic questions. The average farm size in the area surveyed amounted to 49 ha for the 76 private farms and on average 0.45 ha for the 26 household farms. For this paper we excluded households, with a size less than 1 ha and incompatible with the type and size of private farms. Most of the households are also the main consumers of their own grew products themselves. The survey area can be divided into 4 zones, based on weather, water sufficiency and land use conditions. First, farms located in upstream districts: have sufficient water and non-cotton cropped areas; the main crops are wheat, tomato, potato, tobacco and fruits. Second, farms have a good provision of surface and ground water, plain land areas, located north and north-east of Samarkand city. Third, located in the western part of the region, larger farm sizes, severe issues of land salinity resulting from dreadful drainage systems, the main focus on cotton and wheat cultivation, and a lot of farmers are using pump irrigation systems. Fourth surveyed area is the east of Navoiy region and it is located downstream the Zarafshan river, the main crops grown there are wheat and cotton, whereas in the upland areas of the Hatirchi district also grapes and safflower are cultivated.

Farms size characteristics in surveyed area is described in the following table1.

Table1

Farms size characteristics in surveyed are area

Farm size characteristics	Frequency	Average size (ha)	crops grow frequincy in the farms				
			wheat	cotton	tomato	potato	other crops
<25 ha	22	11	18	1	10	6	10
26-50 ha	21	45	21	20	7	1	1
51-75 ha	21	60	21	21	7	0	0
>76 ha	12	104	11	10	5	0	3

Two crops are privileges of the country, which were in the survey study area. The production of Wheat provides a food self – sufficiency to the country, cotton is the main exportable crop, which strengthens the state budget with foreign currency. Average revenue per hectare in surveyed area is higher for potato, grapes, and tomatoes.

One output and 6 inputs are used in the model. Output is represented by gross revenue from all farm crops in a sample. Input resource-variables are contributed as follows:

- Land, crop area
- Water used for irrigate crops
- Tractor and machinery cost
- Fertilizer (includes, fertilizer, organic manure, pesticide and herbicide use) costs

- Labor cost: fixed salary of farm workers, seasonal and part-time workers wages, and family members work calculated as shadow price

Summary statistics of these variables is given in the following table 2.

Table 2

Descriptive statistics on outputs and inputs used in efficiency analysis

	Unit	Minimum	Maximum	Mean	S.D.
Output(crop income whole farming	ThUzSum*	2900	168520	54538	34537
Inputs					
land(farm crop area)	ha	2	148	49	33
water usage	m^3	17130	1518000	351029	264632
seed cost	ThUzSum	1	47976	5012	6053
tractor & machinery(own+rented)	ThUzSum	164	30240	5692	6163
fertilizer (fertilizer, organic manure, pesticides and herbicides use) costs	ThUzSum	119	28085	7440	5303
labour(salary, seasonal and part-time workers wages, family members work calculated as shadow price)	ThUzSum	1512	58800	16551	10955

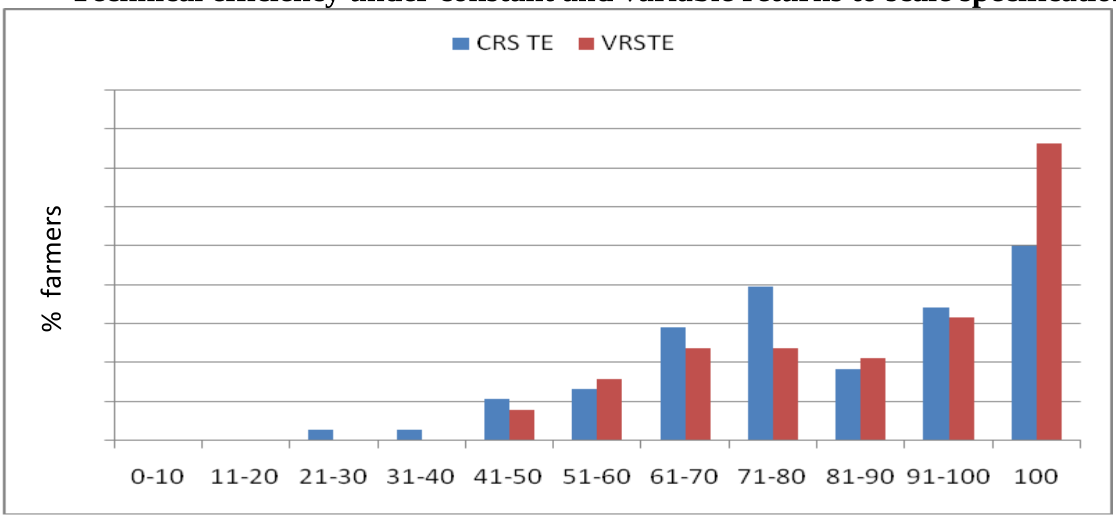
* at the time of survey exchange rate was 1 USD= 1,154 ThUzSum

Results

The analysis of farm performance is carried out using the net crop revenue as an indicator. The findings clearly indicate that input resources are not used efficiently. Two crops, namely cotton and wheat are leading the agriculture of the country, the same being the case for the area of study. In terms of yield per hectare, tomato, potato, onion and fruits are the major cash crops to the rural dwellers. Average revenue per hectare in the survey area is higher for potato, grapes and tomato, which makes them a first choice for farmers. In the surveyed area the average revenue of wheat is rather low, owing to the fact that farmers are getting high quality wheat seeds for high prices and that during the harvesting time they have to hire combines and machinery from MTP (Machinery-Tractor Stations), which is rather cost intensive. Therefore, although the wheat yields in the surveyed area high, wheat production remains a costly undergoing. Farmers with big and medium size farms mostly have their own tractor or farm machinery; nevertheless they have reported having hired additional machinery during the harvesting season. Machinery overuse in some cases has been observed, clearly indicating the inexperience of farmers in certain areas.

Figure 1

Technical efficiency under constant and variable returns to scale specifications



Efficiency classes

Figure1 describes the frequency distribution of the efficiency estimations. The average technical efficiencies for the CRS and the VRS DEA approaches are 0,804 and 0,851 respectively, indicating that substantial inefficiencies occurred in farming operations in the sample. Under the observed conditions, most of the farms were inefficient in CRS and VRS conditions depending on farm sizes. Figure 2 and Figure 3 gives shares of efficiency results by different farms sizes.

Efficiency results by different farm sizes

Figure 2

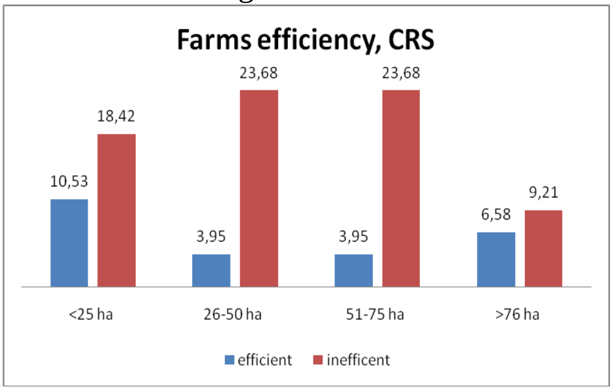
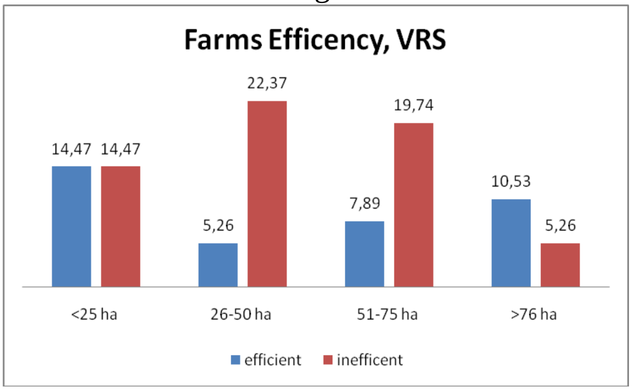


Figure 3



High profit crops for the Zaravshan Valley are potato, watermelon and onion. However, the state order forces farmers to grow cotton and wheat, leaving them with no choice. This leads to huge losses for the farmers and for the government, as the losses of the farmers at times have to be compensated by the state. Compensation is provided by the state in form of subsidies. Subsidies can be indirect, i.e. tax reductions and credits at lower interest rates.
Following table presents the results of the OLS Regression (Table 3)

Table 3

OLS Regression results

```
      Source |       SS       df       MS              Number of obs =      76
-------------+------------------------------           F(  6,    69) =   71.48
       Model |  7.7063e+10     6  1.2844e+10           Prob > F      =  0.0000
    Residual |  1.2399e+10    69   179696605           R-squared     =  0.8614
-------------+------------------------------           Adj R-squared =  0.8494
       Total |  8.9462e+10    75  1.1928e+09           Root MSE      =   13405

------------------------------------------------------------------------------
    Crop_INC |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      LandSz |   329.4507   69.96877     4.71   0.000     189.8668    469.0345
)octoralVis |   2644.777   1834.855     1.44   0.154    -1015.659    6305.213
     seedcst |  -.0155574   .3116138    -0.05   0.960    -.6372099    .6060951
    Tractcst |   .6886123   .2595414     2.65   0.010     .1708414    1.206383
:ertilizcst |   3.856628   .4379914     8.81   0.000     2.982859    4.730397
      labcst |   .3435755   .1626105     2.11   0.038     .0191765    .6679745
       _cons |   -4472.74   4341.818    -1.03   0.307    -13134.43     4188.95
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Conclusions and Outlook

In the surveyed area, the input resources are not used efficiently. The inexperience of newcomers to the agricultural sector makes it an extremely challenging task to be efficient and use the agricultural input resources in a sustainable manner, in soviet times the “kolkhoz” (large state farms) used to take care of all matters related to the farm, thus making the farmer a mere executer of orders. Today the farmer has to manage his farm on his own, making it increasingly difficult for the farmer to be economically and ecologically efficient at the same time. Furthermore, the incentives for being efficient are not provided by the state, as control of land property remains in state hands. The analysis as a novelty also addressed the use of voluntary assistance labor (hashar) based on a shadow-price framework and also tried to incorporate household labor. The use of voluntary assistance for some crops is found to be not economically viable. In terms of technology use, a trend towards de-mechanization could be seen, which is found to be driven by unemployment inside and outside of the agricultural sector. Climate change, which drives water scarcity, aggravates issues of land degradation will be another key aspect to deal with efficiency in the long run. In a next step the idea is to extend the survey to other parts of Uzbekistan and Central Asia to develop adaptive strategies for a new challenging era of farming in Uzbekistan.

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